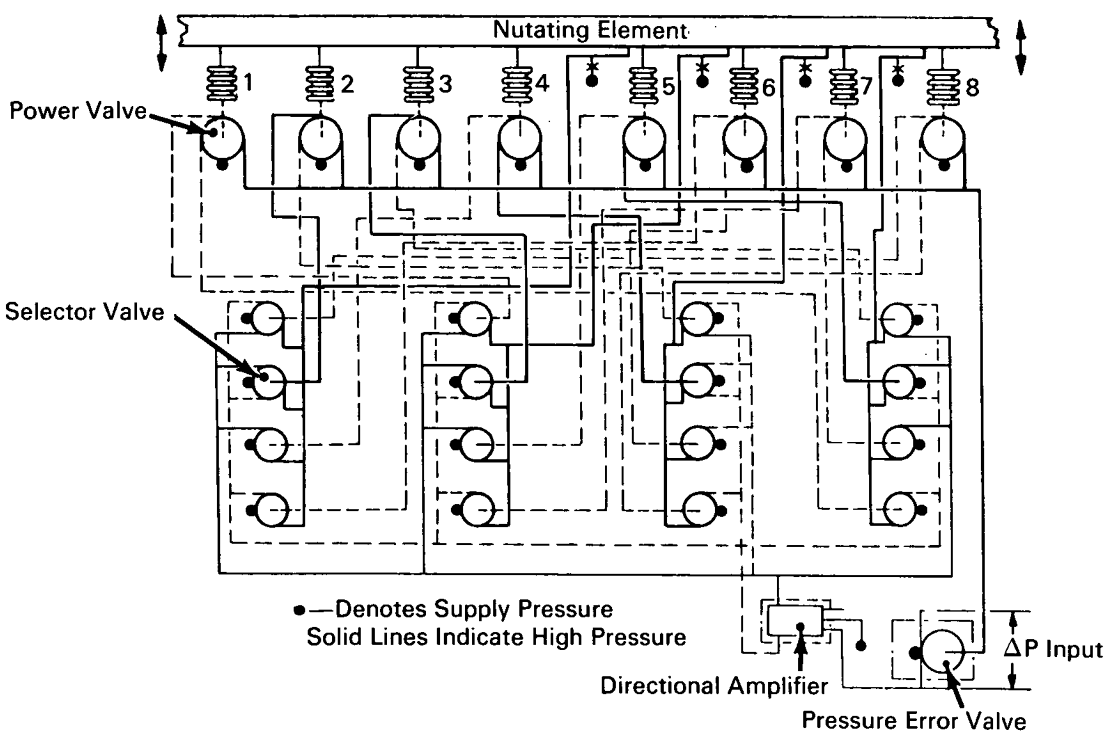
NASA TECH BRIEF

Fluid Logic Control Circuit Operates Nutator Actuator Motor



A fluid logic control circuit has been developed and used to operate a pneumatic nutator actuator motor. The logic circuits have no moving parts and consist of connected fluid interaction (vortex type) devices. The input is a pressure differential which, together with four pressure feedback signals, in this application resulted in a motor output torque proportional in magnitude and direction to the input differential. Commutation is of the analog type, although it can also be of a digital type thus providing unusual versatility. The operation of this circuit demonstrates the ability of fluid interaction devices to operate in a complex combination of series and parallel logic sequence.

The logic circuit, which is shown symbolically consists of:

a. a pressure error valve
b. a bistable directional amplifier
c. eight vortex power amplifiers (one for each bellows)
d. sixteen vortex selector valves
e. four gimbal ring position pickoffs

The power amplifier valves are conventional vortex valves with two outlet ports. One outport port vents

(continued overleaf)

the power flow and the second outlet is connected directly to the bellows chamber. This second outlet is referred to as the "P_0 tap." When no control flow is applied to the power amplifier valve, the greatest impedance to the supply flow is the outlet hole. The vortex chamber pressure and the P_0 tap pressure are then essentially equal to the supply pressure. When a control flow is applied and a swirl is generated in the vortex chamber, the P_0 pressure will reduce to a value equal to or lower than the outlet vent pressure. This reduction in P_0 pressure allows the flow from the bellows (due to the bellows stroke) to cross the vortex chamber and vent through the outlet.

To understand the logic sequence of the circuit it is important to remember that the power valve bias flow is always greater than the signal from the selector valves. In the absence of a selector valve output, the bias flow would cause complete turndown of the eight power valves, resulting in a minimum bellows pressure. Flow from a selector valve will tend to reduce the effectiveness of the bias flow and result in an increase in the bellows pressure. The maximum pressure obtainable in the bellows will then depend on the magnitude of the bias flow relative to the selector valve output. Therefore a high bias flow will result in a low bellows pressure and vice versa. The bias flow is determined by the pressure error valve which in turn is controlled by the input pressure differential.

Since the control ports in the pressure error valve are opposing, an input pressure differential in either direction will generate a swirl and reduce the output or bias flow. The maximum obtainable bellows pressure is therefore directly proportional to the magnitude of the input error signal.

The directional amplifier is a bistable flip-flop.This unit provides a constant flow to one of two outputs depending on the sign of the input error signal. The flow determines the direction of rotation of the actuator.

The 16 selector valves can be considered in groups of 4. Each group has as inputs the directional signals from the bistable amplifier and one of the four pickoff pressures. The pickoff pressure is the intermediate pressure obtained between an upstream fixed orifice and a downstream variable bleed.

Each group of selector valves consists of two pairs, each operating in push-pull fashion. The direction signal pressure determines which pair are functioning and which pair remain in full turndown, when the pickoff pressure varies. The outputs of each pair of selector valves are connected through the corresponding power valves to bellows which are 180° apart, and each pair of the group of four connect to bellows which are displaced by 90°.

The selector valve outputs will then control the power valves to maintain four of the eight bellows at a high pressure level and the opposed four at a low pressure level. The bellows are attached to an input bevel gear mounted in a pair of gimbal rings which allow the input gear to wobble or nutate but not rotate. The input gear mates with an output bevel gear which is free to rotate but not to nutate. When force is applied at a point on the circumference of the input gear, the gears will mesh along the pitchline of a single tooth. By moving the point of application of the force around the circumference, the input gear will mesh consecutively with each tooth of the output gear. If the output gear has one less tooth than the input gear, the output gear will be displaced by one tooth for each complete nutation of the input gear. Gear reductions between 50:1 and 200:1 can be accomplished by a single pair of gears. When the directional signal is reversed, the bellows pressures change to shift the force centroid by 90° across the mesh point, resulting in a torque moment in the opposite direction.

Notes:

1. Additional details are contained in NASA CR-54788, "Pneumatic Nutator Actuator Motor," by G. R. Howland of the Bendix Corporation. The report may be obtained from the Clearinghouse for Federal and Scientific Information, Springfield, Virginia 22151.
2. Inquiries concerning this invention may be directed to:

   Technology Utilization Officer
   Lewis Research Center
   21000 Brookpark Road
   Cleveland, Ohio 44135
   Reference: B66-10593

Patent status:

Inquiries about obtaining rights for the commercial use of this invention may be made to NASA, Code GP, Washington, D.C. 20546.

Source: The Bendix Corporation
under contract to
Lewis Research Center
(Lewis-294)